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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

April 7, 2000

VIA HAND DELIVERY
Ms. Magalie Roman Salas, Secretary
Federal Communications Commission
The Portals, 445 12th Street, S.W.
Room TW-B204
Washington, D.C. 20554

Re: Cost-Based Terminating Compensation for CMRS Providers
CC Docket Nos. 95-185, 96-98, and 97-207

Dear Ms. Salas:

Pursuant to section 1.1206(a)(1) of the Commission's rules, Sprint PCS is filing an original and six copies of the attached cover letter and white paper concerning the above referenced proceedings. The letter is directed to Thomas J. Sugrue, Chief of the FCC's Wireless Telecommunications Bureau and Lawrence E. Strickling, Chief of the FCC's Common Carrier Bureau.

The letter introduces the white paper, which was prepared for Sprint PCS by Bridger Mitchell and Padmanabhan Srinagesh of Charles River Associates. The white paper describes an economic methodology for determining the additional costs of terminating traffic on a CMRS network.

Please contact the undersigned with any questions.

Sincerely,

Jonathan M. Chambers

Cc. William Bailey, Senior Attorney, Competitive Pricing Division. Common Carrier Bureau
Dale Hatfield, Chief, Office of Engineering and Technology
Jane Jackson, Chief, Competitive Pricing Division, Common Carrier Bureau
Stacey Jordon, Economist, Wireless Telecommunications Bureau
Kris Montieth, Chief, Policy Division, Wireless Telecommunications Bureau
Tamara Preiss, Deputy Chief, Competitive Pricing Division, Common Carrier Bureau
James Schlichting, Deputy Bureau Chief, Wireless Telecommunications Bureau
Janet Sievert, Deputy Chief, Policy Division, Wireless Telecommunications Bureau
Walt Strack, Chief Economist, Policy Division, Wireless Telecommunications Bureau
Yog Varma, Deputy Bureau Chief, Common Carrier Bureau

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April 7, 2000

Thomas J. Sugrue, Chief
Wireless Telecommunications Bureau
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, D.C. 20554

Lawrence E. Strickling, Chief
Common Carrier Bureau
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, D.C. 20554

Re: Cost-Based Terminating Compensation for CMRS Providers
CC Docket Nos. 95-185, 96-98, and 97-207

Dear Messrs. Sugrue and Strickling:

On February 2, 2000, I submitted a letter and legal memorandum to the Commission on the subject of cost-based compensation for CMRS providers pursuant to the pricing standards of section 252(d)(2) of the Communications Act. As a follow-up to that memorandum, I am sending a white paper prepared for Sprint PCS by Bridger Mitchell and Padmanabhan Srinagesh of Charles River Associates. The paper describes an economic methodology for determining the additional costs of terminating traffic on a CMRS network.

Please contact me if you have any questions.

Respectfully submitted,

Jonathan M. Chambers

Attachment: Transport and Termination Costs in PCS Networks: An Economic Analysis

Charles
River
Associates

TRANSPORT AND TERMINATION COSTS IN PCS NETWORKS:

AN ECONOMIC ANALYSIS

April 4, 2000

Prepared by

Bridger M. Mitchell and Padmanabhan Srinagesh

CRA

Table of Contents

Executive Summary

This paper describes a methodology for calculating the additional costs of terminating interconnected local calls on Personal Communications Services (PCS) networks. It focuses on forward-looking economic cost, an analytical framework established by the Federal Communications Commission (the Commission) for conducting cost studies to calculate rates for the transport and termination of calls on the networks of Local Exchange Carriers (LECs) and Commercial Mobile Radio Service (CMRS) networks. The application of forward-looking principles to PCS networks raises significant issues of implementation that were not considered by the Commission in its analysis of wireline networks. This paper seeks to resolve these issues through the application of the basic principles developed by the Commission for wireline networks.

Section 1 of the paper analyzes the Commission's definitions of transport and termination of interconnected calls that originate on one local network and terminate on a second local network. We conclude that, for the purpose of computing the additional cost of terminating interconnected calls on PCS networks, we need not distinguish between transport and termination. Section 2 reviews the regulatory framework governing symmetric and asymmetric reciprocal compensation arrangements between PCS providers and incumbent Local Exchange Carriers (LECs). Section 3 reviews the Commission's forward-looking economic cost and additional cost standard governing reciprocal compensation charges, and concludes that the forward-looking costs of all traffic-sensitive network elements can be recovered in charges for transport and termination. Analyzing each component of a PCS network, we conclude that the costs of all components, excepting those of PCS handsets, are additional costs as defined by the Commission. Section 4 considers specific issues of modeling PCS network costs, including the increment whose cost is to be determined, the use of levelized prices, and the forward-looking cost of spectrum licenses.

1 Defining Transport and Termination in Wireline and Wireless Networks

The Telecommunications Act of 1996 provides that all LECs have "[t]he duty to establish reciprocal compensation arrangements for the transport and termination of telecommunications."[1] The Act also states that the terms of such arrangements shall not be considered just and reasonable unless "such terms and conditions provide for the mutual and reciprocal recovery by each carrier of costs associated with the transport and termination on each carrier's network facilities of calls that originate on the network facilities of the other carrier."[2] The term "transport and termination" is not defined in the Telecommunications Act of 1996. In its Local Competition Order,[3] the Commission has defined transport and termination for incumbent and non-incumbent LECs as two distinct services. This section summarizes the Commission's definition and analyzes its applicability to PCS networks. We conclude that it is not necessary to treat transport and termination in a PCS network as two distinct services.

1.1 The Commission's Definition of Transport and Termination

In its Local Competition Order, the Commission determined that transport and termination are two functions, not one. *Transport* is defined as the "transmission of terminating traffic that is subject to section 251(b)(5) from the interconnection point between the two carriers to the terminating carrier's end office switch that directly serves the called party (or equivalent facility provided by a non-incumbent carrier)." *Termination* is defined "as the switching of traffic that is subject to section 251(b)(5) at the terminating carrier's end office switch (or equivalent facility) and delivery of that traffic from that switch to the called party's premises."[4] For CMRS-wireline interconnection, "traffic between an incumbent LEC and a CMRS network that originates and

[1] Telecommunications Act of 1996, 47 U.S.C. §251(b)(5).

[2] Telecommunications Act of 1996, 47 U.S.C. §252(d)(2)(a)(i).

[3] *Implementation of the Local Competition Provisions in the Telecommunications Act of 1996*, First Report and Order, CC Docket No. 96-98, (released August 8, 1996). Henceforth, "Local Competition Order."

[4] Local Competition Order at ¶1039-1040.

terminates within the same MTA (defined based on the parties' locations at the beginning of the call)" is subject to section 251(b)(5).[5] The definitions of transport and termination apply to interconnection arrangements between a wireless and a wireline network, as well as to interconnection arrangements between two wireline networks.

1.2 Transport and Termination on ILEC Networks

It is technically feasible for a local carrier to obtain interconnection at an incumbent LEC's (ILEC's) tandem switch, and purchase transport and termination to subscribers served by all end offices that subtend the tandem, or alternatively to obtain interconnection at an ILEC's end office and purchase only termination to all subscribers served by that end office. By providing for separate rates for transport and for termination, the Commission has allowed interconnecting carriers to determine whether they will interconnect at an ILEC's tandem office and purchase both transport and termination from the ILEC, or whether they will interconnect at the ILEC's end office and purchase only termination services from the ILEC. The Commission has noted that many alternatives exist for the transport service provided by the ILEC, including dedicated lines provided by other carriers and the ILEC's unbundled network elements, making the purchase of only termination services from the ILEC a viable alternative. The unbundling of transport and termination on an ILEC's network serves to promote competition by permitting entrants to avail themselves of low-cost alternatives to an ILEC's transport service when such alternatives are available.

1.3 Transport and Termination on PCS Networks

In this section we demonstrate that, for the purpose of computing the additional cost of transport and termination on a PCS network, there is no need to distinguish between a transport service and a separate termination service. To facilitate our economic analysis, we provide a brief overview of a PCS network, describing its architecture and the role played by each major

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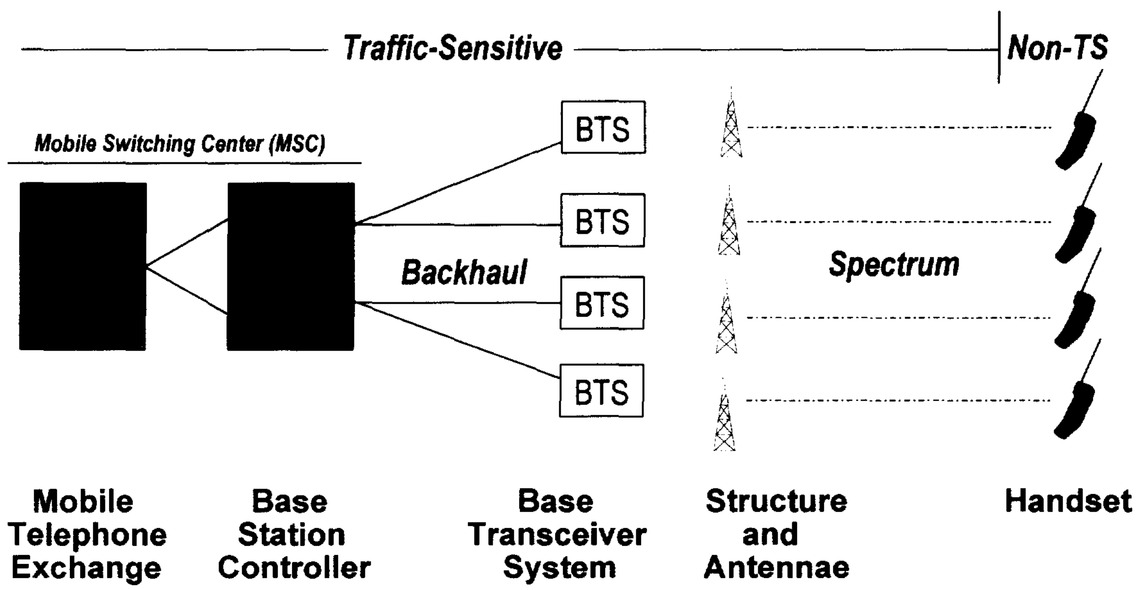
[5] Local Competition Order at ¶1043.

network component in originating, carrying, and terminating calls. We then identify the points of interconnection on a PCS network at which other LECs can deliver local calls destined to the PCS network's subscribers.

1.3.1 The Architecture of a PCS Network

Figure 1 provides a stylized diagram showing the major network components of a PCS network. The functions performed by these components may be explained by tracing a call through the network.

Figure 1: PCS Network Architecture



A PCS call originates on a subscriber's handset. The handset converts the voice signal to digital form in accordance with one of several standards and transmits the signal using available spectrum to a nearby cell site. At the cell site, the signal is received by an antenna, which is often placed on a supporting tower.[6] The signal is then processed by electronic equipment contained in a Base Station Transceiver System (BTS) located at the cell site[7] and converted into a different form that is suitable for transmission to a Base Station Controller (BSC). The converted signal is transported to the BSC over a microwave or wireline backhaul link.

The BSC ordinarily controls several cell sites and performs a number of key functions that include traffic concentration, supervision of call hand-off from one BTS to another as the subscriber travels through the Major Trading Area (MTA), administration of BTS resources, network management, and operations and maintenance. The BSC aggregates traffic from several subscribers and routes the aggregated traffic over another link to the Mobile Switching Center (MSC), which houses a mobile voice switch or Mobile Telephone Exchange (MTX). The MTX, in conjunction with an Intelligent Network Platform and its associated signaling network, performs call set-up and switching functions. In addition, it has several other capabilities including authentication, location registration, and billing. The MTX is connected to other MTXs, to an Intelligent Network platform over a signaling network based on the SS7 standard, and to switches operated by wireline LECs and other carriers.

Spectrum and capacity in a BTS, a BSC, backhaul links, and MTX(s) are dedicated to a call for its duration. When the call is terminated, those resources are released and can be used to support another call. Resources in the Intelligent Network platform and the associated signaling network are dedicated to a call attempt during the call set-up procedure and to call terminations during the call tear-down procedure, during which time they are unavailable for processing other calls.

A terminating call is processed in the reverse order. The call arrives over an interconnection trunk at the MTX that is "home" to the subscriber's directory number. If the subscriber is currently registered with the MTX (i.e., if the subscriber is currently at a location served by that MTX), the MTX routes the call to a BSC, which assigns a BTS the resources necessary to

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[6] For cell sites located on rooftops, a tower is not necessary.

[7] For expositional convenience, we will use "cell site" to refer to the BTS, antennas, and towers, if needed.

establish the required connection between the PCS network and the subscriber's handset. Otherwise, when the MTA is served by multiple MTXs, location registers are consulted. If the subscriber is within the MTA but not in the territory served by his home MTX, the call will be routed from the home MTX on an inter-machine trunk to the MTX serving the subscriber's current location. The second MTX routes the call to a BSC, and the standard call set-up procedure is then followed. For these calls, multiple switching occurs within the PCS network. During call set-up and call tear-down, resources of the Intelligent Network platform and the associated signaling network are used. Network components used to originate a call are also used to terminate a call.

1.3.2 Transport and Termination Is a Single Service on a PCS Network

LECs seeking to interconnect to a PCS network have technically feasible points of interconnection available at only one network level -- all calls to a wireless operator's subscriber that originate on another LEC's network are delivered to an MTX. Nodes at other levels of the PCS network, such as BSCs and BTSs, are not capable of routing calls to that subscriber and there is currently no technically feasible alternative point of interconnection at these levels that is available to an interconnecting LEC. The Commission's distinction between transport and termination, which was based on the ability of LECs to select among alternative points of interconnection at different levels of an ILEC's network and to purchase alternatives to ILEC-supplied transport services, does not apply to a PCS network.

Since a PCS network offers only one level with technically feasible points of interconnection, the relevant concept in a PCS network is a single service that provides both transport and termination. In our analysis we will treat transport and termination on a PCS network as a single, indivisible service that transports interconnected calls from the point of interconnection at an MTX to a subscriber's handset.

2 Symmetric and Asymmetric Reciprocal Compensation Arrangements

The Telecommunications Act of 1996 requires that reciprocal compensation for interconnected calls be based on a "reasonable approximation of the additional costs of terminating such calls."[8] The Commission has determined that in an incumbent LEC's network, while the end office switch and the loop are used for call termination, the additional cost of termination "primarily consists of the traffic sensitive component of local switching," which can be approximated by "that portion of the forward-looking economic cost of end-office switching that is recovered *(sic)* on a usage-sensitive basis."[9] The additional cost of transport for an ILEC can be developed by applying the Commission's forward-looking cost methodology to the elements used to transport calls from the point of interconnection to the end office switch directly serving the called party.[10]

2.1 Symmetric Rates

Reciprocal compensation between networks is presumed by the Commission to be just and reasonable when it is *symmetric*.[11] Under symmetric rates the incumbent LEC and the interconnecting carrier charge each other the same rate for transport or for transport and termination per unit of interconnected traffic. For calls delivered by an incumbent to a non-incumbent facility that is equivalent to an incumbent's end office switch, the ILEC will be charged the (symmetric) termination rate. For calls delivered to a facility that is not equivalent to an incumbent's end office switch, the incumbent will be charged the rate for transport and termination. Under symmetric reciprocal compensation arrangements, the rate that is charged by the non-incumbent is in part determined by the facility in the non-incumbent's network that is deemed to be the equivalent of an incumbent's end office switch.

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[8] Telecommunications Act of 1996, 47 U.S.C. §252 (d)(2)(A)(ii).

[9] Local Competition Order at ¶1057. The Commission's use of "recovered" rather than "incurred" appears to conflate categories of cost with principles of rate-setting.

[10] Local Competition Order at ¶1054.

[11] Local Competition Order at ¶1089.

2.2 Asymmetric Rates

While symmetric compensation rates might be justifiable when the interconnecting networks have similar cost structures, the Commission has made allowances for cost differences in wireless (and other) networks. Reciprocal compensation rates for the transport and termination of local telecommunications traffic may be asymmetric "... if the carrier other than the incumbent LEC (or the smaller of two incumbent LECs) proves to the state commission on the basis of a cost study using the forward-looking economic cost based pricing methodology ... that the forward-looking costs for a network efficiently configured and operated by the carrier other than the incumbent LEC (or the smaller of two incumbent LECs) exceed the costs incurred by the incumbent LEC ...".[12]

To identify the principles used to arrive at the additional costs of completing interconnected calls, in the next section we describe the Commission's forward-looking cost methodology and its application to transport and termination services, first on an ILEC's network and then on PCS networks.

3 Forward-Looking Cost Methodology

The Commission has concluded that the pricing standards for interconnection and unbundled network elements as well as for transport and termination of traffic "are sufficiently similar to permit the use of the same general methodologies for establishing rates under both statutory provisions."[13] The forward-looking economic cost of a network element (or service)[14] provided by an incumbent LEC is defined by the Commission to be the long-run cost of the facilities that are directly attributable or incremental to that element, given the incumbent LEC's provision of other elements in a *status quo ante,* or baseline, scenario. In this approach all inputs are

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[12] 47 C.F.R. §51.711 (b).

[13] Local Competition Order at ¶1054.

[14] In the subsequent discussion, we will use "element" for "element or service."

considered variable. Using the most efficient currently available technology, the least-cost network configuration that supports the specified services is computed. Investments are converted to monthly costs using a forward-looking cost of capital and depreciation schedules based on the assets' economic lives. Ongoing costs of operating and maintaining the asset are then added to obtain the forward-looking cost of the element.[15] Finally, this cost is increased by a reasonable allocation of forward-looking common costs to obtain the cost-based rate of the network element or service.

3.1 The Additional Cost of Transport and Termination on ILEC Networks

For ILEC networks, the Commission has determined that the stand-alone cost of a narrowband network capable of providing current levels of local exchange, exchange access, and leased line services should be determined.[16] The cost of any element is obtained by identifying the network facilities used by the element, and attributing the appropriate share of the costs of these facilities to the element in question. The costs are expressed on a per-unit basis, where the denominator is the entire volume of the element in question, including the amounts of the element sold to competitors and the amount that is self-supplied.

For transport and termination of local traffic, customary points of interconnection are the trunk-side of an end office's local switch or the trunk interconnection point for a tandem switch. If the point of interconnection is at an end office, the forward-looking economic cost of termination includes the additional costs of switching that traffic at the end office, transporting it to the subscriber's premises and terminating it at a Network Interface Device located at the customer's premises. If the point of interconnection is at a tandem switch, the additional costs also include the forward-looking costs of switching the traffic at the tandem and transporting the traffic to the end office.

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[15] 47 C.F.R. §51.505.

[16] The network configuration takes the existing location of the incumbent LEC's wire centers as given.

A carrier that interconnects at an ILEC's end office uses the capacity of several LEC network elements, principally the local switch and the local loop, to complete a call originating on its network. The Commission has found that the *additional* costs of terminating such calls consist primarily of the traffic sensitive component of local switching.[17] For the traffic sensitive component of local switching, the Commission includes "the switching matrix, the functionalities used to provide vertical features, and the trunk ports."[18] The Commission explicitly excludes from termination costs the costs of other facilities, finding that "The costs of local loops and line ports associated with local switches do not vary in proportion to the number of calls terminated over these facilities. We conclude that such non-traffic sensitive costs should not be considered 'additional costs' when a LEC terminates a call that originated on the network of a competing carrier."[19] The rationale used by the Commission is clearly stated: *all* traffic sensitive costs and *only* traffic sensitive costs should be included in the additional costs of termination.

A carrier that interconnects at an ILEC's tandem office utilizes tandem switching and transmission provided by the ILEC to transport its call to the end office serving the called party. The Commission concluded that the costs of this transport should be based on the costs of the corresponding network elements (tandem switching and shared or common interoffice transport) as determined by a forward-looking methodology.[20] In formulating its rate structure standards, the Commission determined that tandem switching costs and the costs of shared transmission facilities "may be recovered through usage-sensitive charges or in another manner consistent with the manner in which the incumbent LEC incurs those costs."[21]

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[17] Local Competition Order at ¶1057.

[18] 47 C.F.R. §51.513 (c) (2).

[19] Local Competition Order at ¶1057.

[20] Local Competition Order at ¶1061.

[21] 47 C.F.R. §51.509 (d) and (e).

The Commission's forward-looking cost methodology applied to ILEC networks is based on the fundamental principle that the costs of all traffic sensitive network elements used for transport and termination should be included in reciprocal compensation rates, while the costs of all non-traffic sensitive elements should be excluded.

3.2 The Additional Costs of Transport and Termination on a PCS Network

The service whose forward-looking economic cost is to be determined is the termination of calls to PCS subscribers that originate on another network. A large number of network components are used to terminate such calls -- the handset, the wireless link to the cell sites in the MTA, the cell sites including the towers (if any), antennas and BTSs, microwave or wireline links from the cell sites to the BSCs, links from the BSC to the MTX, the MTXs in the MTA, and the links connecting the MTXs in the MTA. In addition, an Intelligent Network platform and the associated SS7 signaling network are required for call origination and termination. The analysis of this section uses the Commission's general rate structure standard to help identify which of these components has traffic sensitive costs.

The general rate structure standard that the Commission has adopted for the pricing of network elements states that: "The costs of dedicated facilities shall be recovered through flat-rated charges. The costs of shared facilities shall be recovered in a manner that efficiently apportions costs among users. Costs of shared facilities may be apportioned either through usage-sensitive charges or capacity-based flat-rated charges, if the state commission finds that such rates reasonably reflect the costs imposed by the various users."[22]

To apply the Commission's rate standard in a wireless network, we inquire whether each component of a PCS network is shared by several users or whether it is dedicated to a single user. Next, we consider whether each component's costs are traffic sensitive. Our analysis finds that handsets are resources dedicated to individual users and their costs are not traffic sensitive,

[22] 47 C.F.R. §51.507 (b) and (c).

while all of the other components are shared among users of the wireless network and the costs of those elements are traffic sensitive.

The Commission's distinction between dedicated and shared resources is important in determining whether an increase in interconnected traffic increases the total (forward-looking) costs of supplying service. A subscriber can make greater use of a dedicated resource – for example, increased calling over a wireless handset or an incumbent's local loop – without causing the network supplier to incur additional costs for that dedicated resource. In contrast, shared resources that are placed in a common pool and drawn on for the duration of a call or during call set-up and call tear-down have very different cost characteristics. For example, in the long run added minutes of calling handled by a network switch or trunk require that the capacity of that resource be increased in order to maintain service quality for other users. Thus, the costs incurred by the network supplier for a shared resource increase when the volume of calling increases.

3.2.1 Wireless Handsets

A circuit board in a wireless handset performs most of the BORSCHT functions that are provided by a line card in a traditional end office switch.[23] For a wireline network the Commission has included the cost of a line card in the flat-rated charge for the unbundled switching network element, but has ruled that it is not an "additional cost" of terminating a call since each line card is dedicated to a single customer, and since the cost of a line card is non-traffic sensitive.[24] Similarly, in a wireless network, a handset including its battery and its circuit

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[23] BORSCHT is an acronym for Battery power, Overvoltage protection, Ringing current supply, Supervision, Coding and decoding (digital-analog), and Hybrid Testing (two wire to four wire conversion). It is provided by the interface module of an end office switch, which contains the line card. (See "Benchmark Cost Proxy Model," Release 3.1, Model Methodology, April 30, 1998 edition, pages 62-63; and Local Competition Order at footnote 913.) In a PCS network, Overvoltage protection and Hybrid Testing are not required because there is no direct electrical connection between the handset and the network. A battery and a circuit board in the handset provide the remaining BORSCHT functions.

[24] The Commission "found that the 'additional cost' to the incumbent LEC of terminating a call that originates on another network includes only the usage-sensitive costs, including the switching matrix and the trunk ports, but not the non-traffic sensitive costs of the local loops and line ports associated with the local loops." *In the*

board is dedicated to one end user, and its cost is non-traffic sensitive. Applying the Commission's principles and its analysis of line cards in wireline networks, we conclude that the costs of wireless handsets are not additional costs associated with terminating calls.

3.2.2 Spectrum

The spectrum channel used to support voice communications on the link between subscriber handsets and cell sites is a shared resource. It is assigned to a subscriber from the pool of available channels only for the duration of a call and is then released for use by another call. While a variety of access technologies are used to allocate this spectrum, none dedicates capacity to any one subscriber on a full-time basis.[25] The shared spectrum channel that links a handset to a cell site is unlike a wireline loop, which provides a dedicated, full-time voice communications path between a user and the end office switch. The spectrum is also unlike a dedicated transport service which reserves capacity for a particular user even when the user is not communicating. Instead the spectrum most closely resembles common transport, in that both place resources in a pool that can be allocated to any user on an as-needed basis.

With a fixed quantity of spectrum, an increase in peak-hour wireless traffic can lead to increased blocking rates and increased call drop-off as users move from a cell site with adequate capacity to one that is congested.[26] In the short run, if other inputs such as the number of cell sites were held constant, more spectrum would be needed to maintain a constant quality of service when

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Matter of Implementation of Local Competition Provisions in the Telecommunications Act of 1996, CC Docket 96-98, Order on Reconsideration, Released September 27, 1996, at ¶6.

[25] Frequency Division Multiple Access (FDMA), Time Division Multiple Access (TDMA), and Code Division Multiple Access (CDMA) are the three common methods used to allocate bandwidth to a call. FDMA allocates frequencies to individual calls at call set-up, TDMA allocates time slots, and CDMA allocates codes, of which there is a limited number available. When a handset is not in use, the BTS may communicate periodically with the handset over a control channel, but no bandwidth is dedicated to any individual handset for voice communications.

[26] See "Frustrated Love," *Wall Street Journal*, July 19, 1999, p. A1.

offered traffic exceeds the capacity of the available spectrum. The costs of using spectrum resources are therefore traffic sensitive in the short run.

In the long run, when other inputs are not constant, wireless providers have incentives to meet increased demand by selecting the least-cost combination of additional inputs. Given the substitutability of spectrum for other inputs such as cell sites (see the discussion of cell splitting below), increased use of *both* spectrum *and* its substitutes can be expected in the long run as demand increases. We conclude that spectrum costs are traffic sensitive and should be included in the additional costs of transport and termination service.

3.2.3 Cell Sites

A cell site provides call set-up functions, call management, and a wireless interface to all handsets within a specific geographic area or cell. It includes antennas, supporting towers where necessary, and the BTS. All three components of the cell site are needed to maintain a wireless connection to a user's handset.

Antennas are necessary to transmit wireless signals from a cell site to a subscriber handset, and to receive wireless signals from wireless handsets in the area covered by the cell site. The antennas and equipment are often placed on a *tower* dedicated to the cell, or on a rooftop. Towers or rooftop sites help ensure adequate signal strength between handsets across the cell and the antenna at the cell site. The height of the tower, the size of the antenna, and the rental for the cell site are driven in large part by the topography of the cell and by local conditions.

BTSs contain the electronics necessary to convert the signal received from the antenna into a format suitable for transport to a BSC, and to perform translations in the reverse direction. The BTS also amplifies signals for broadcast over the air interface, communicates call set-up information with the handset, provides timing information, and manages handoffs from one sector to another sector within the same cell site.

The ability of a BTS to carry traffic is limited by the capacity of its processor unit, which is used to translate formats, control power, supervise call set-up, and manage internal handoffs. When the volume of calls increases sufficiently, the installed capacity of the BTS will be exhausted, and the number of calls being blocked or dropped will increase. The quality of service can be maintained by increasing the capacity of the BTS. PCS network operators can augment capacity in two primary ways — the addition of radio carriers or the addition of cell sites.

When the initial calling volume is still relatively low, the electronic equipment at the cell site is initially configured to use only a portion of the available radio spectrum. In this case, capacity can be expanded by adding, at some cost, electronic equipment to the BTS that permits additional "radio carriers" (frequencies that were previously unused) to be brought into service. Since calling volume triggers the level of investment in BTSs, the costs of BTSs are traffic sensitive.

The costs of the structures required to house BTSs and antennas are akin to the costs of the land and buildings required to house an incumbent LEC's wire centers. The Commission has determined that these costs can be recovered by incumbents as part of the unbundled local switching element, and the model adopted by the Commission to compute the forward-looking cost of unbundled network elements includes the costs of land and buildings in its estimate of the cost of local switching.[27] By the same logic, the costs of structures at cell sites can be considered part of the costs of BTSs.

A second method of expanding capacity is cell splitting. When total minutes of use exceed the capacity of a cell site, relief can be obtained by adding an additional cell site at an adjacent location. This permits the new site to manage a portion of the traffic being transmitted in that geographic area, thus "splitting" the original cell. When all available spectrum is exhausted and carriers cannot be added, cell splitting may be the only means of expanding capacity. Also, it is frequently more efficient to split a single cell than to add additional carriers or frequencies to the network. At some point, however, cell density cannot be increased without causing interference and carriers must be added.

Cell splitting provides an independent and alternative justification for the conclusion that all costs associated with cell sites are traffic sensitive. A forward-looking engineering design that minimizes the cost of a wireless cell-based network adapts the size of a cell to the expected peak usage in a cell. In a low-volume rural market, the number of channels contained in, for example, 10 megahertz (MHz) of spectrum may be sufficient to meet peak demand throughout the market. The least-cost design for a rural market may consist of a single cell site with all channels shared by subscribers throughout the cell. In a metropolitan market with the same geographic extent, usage is likely to be considerably higher. Even with a 30 MHz license, it may be necessary to deploy several smaller cell sites. With limited spectrum, the total costs of cell sites will be higher in the high-traffic metropolitan area with multiple sites than in a low-traffic rural area network with a single site. By the same token, when the amount of spectrum is fixed and demand in an area grows beyond thresholds established by engineering design, cell splitting may be required to meet demand while maintaining traditional quality standards. The volume of traffic therefore determines the number of cell sites.

In the long run, when all inputs are variable, wireless providers will use a combination of more spectrum (if suitable spectrum is available) and cell splitting to meet increased demand. In this long-run context, all costs associated with cell sites are appropriately treated as traffic sensitive costs to be included in computing the additional cost of terminating interconnected calls.

3.2.4 Backhaul Links

The backhaul links connecting BTSs to BSCs and BSCs to MSCs are typically microwave links or T-1 lines that carry both voice paths and channels for signaling and control. Bandwidth on these links is a shared resource that is kept in a pool and assigned to calls on an as-needed basis. When traffic volumes increase, additional link capacity is required to maintain a constant grade of service. When a BSC is collocated with a MTX in a MSC, the least-cost option for backhaul

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[27] *In the Matter of Federal-State Joint Board on Universal Service*, Tenth Report and Order, CC Docket 96-45 (released November 2, 1999) at ¶417.

is typically cabling and cross-connect equipment located within that office.. In other cases, the least-cost option for obtaining backhaul links is most likely to be private line services offered by the incumbent LEC or competitive LECs.

When the BSC is collocated in the MSC, the backhaul links can be installed in relatively small increments. As traffic increases, the installed capacity will be exhausted and more link capacity will be required. Backhaul links installed within a MSC by the PCS operator are therefore traffic sensitive. For purchased backhaul links, current tariffs typically set higher rates for higher capacity links. Therefore, the costs incurred by a PCS network operator for all backhaul links, whether self-provided or leased, are traffic sensitive.

3.2.5 Base Station Controllers

A BSC mediates between an MTX and BTSs. It is responsible for monitoring the BTSs that subtend it and for allocating BTS resources to calls. It also manages call hand-offs from one cell site to another when a mobile subscriber changes location during a call and provides the necessary voice coding or "vocoding" that permits the efficient and high-speed transmission of voice in a wireless network.

None of the capacity of a BSC is dedicated to a subscriber. While a subscriber is making a call, a portion of the BSC's capacity (both processor capacity and trunk interfaces) is consumed by that call and is unavailable to serve other calls. These BSC resources are released when the call is disconnected. BSC resources are shared, and their costs are driven by the volume of traffic. In addition, when increases in traffic lead to cell splitting, the number of BTSs increases. Given technical limits on the number of BTSs that a BSC can control, cell splitting will lead to an increase in the number of BSCs required. For both these reasons, the costs of BSCs are traffic sensitive.

3.2.6 Mobile Telephone Exchange

The MSC houses a voice switch, referred to as an MTX, which plays a role in call set-up, call routing, switching, and the generation of call detail records; it also performs additional functions needed for mobile service, including maintaining the location registration of subscribers. However, the MTX is a shared network component and has no line cards or other resources dedicated to any subscriber. The central processor and switching matrix of the MTX and the trunk ports connecting the MTX to other elements of the PCS network are traffic sensitive investments. In order to maintain an acceptable grade of service, these elements of the MTX need to be augmented as traffic increases. As with wireline networks operated by ILECs, a single switch does not have sufficient capacity to process all the calls in many densely populated metropolitan areas, which then require multiple switches. Since MTXs do not have line-side connections, the decision to install a second (or subsequent) MTX is driven entirely by the volume of traffic.[28] Given the shared and traffic sensitive nature of MTXs, a forward-looking economic cost-based methodology should include all MTX costs in the additional costs of call completion.

3.2.7 The Intelligent Network Platform and Signaling System

The intelligent network platform and the signaling system used by PCS networks are similar to those used by ILECs in their networks. The packet switches and signaling links have limited capacity to process and transport the messages generated during call set-up. At higher calling volume, additional capacity will be required to ensure that the proportion of completed calls does not fall below acceptable thresholds. Similarly, the capacity of the hardware on which the intelligent network platform is based must be augmented as calling volumes increase. Therefore, the costs of the intelligent network platform and the associated signaling network are traffic sensitive.

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[28] In forward-looking cost models of wireline networks, a second switch may be required if the number of lines served exceeds an engineering threshold, even if processor capacity is not fully utilized. In a PCS network this consideration is absent.

4 Modeling Forward-Looking Costs in a PCS Network

In this section, we discuss several important issues that arise in constructing a forward-looking cost model of a PCS network. These issues include the assumed increment whose forward-looking cost is to be computed, the use of a three-year study period, and the economic basis for modeling spectrum costs.

4.1 Defining the Baseline Scenario, the Increment, and the Volume of Demand

The cost of providing a given increment of service, such as the transport and termination of interconnected calls depends on the *baseline* network to which the increment of output is added. For the purposes of computing universal service funding requirements, the Commission has determined that incumbent LECs should assume a *scorched node* baseline, with the locations of wire centers given but no infrastructure in place. A network capable of supporting the demands of residence and business customers for supported services is the increment that is added to the scorched node baseline.[29]

For a network element, the Commission has defined the Total Element Long Run Incremental Cost (TELRIC) as "the forward-looking cost over the long run of the total quantity of the facilities and functions that are directly attributable to, or reasonably identifiable as incremental to, such element, calculated taking as a given the incumbent LEC's provision of other elements."[30] Total network element costs are then converted to a per-unit cost by dividing by a reasonable projection of the total units of the element used by the ILEC plus the total units provided to requesting telecommunications carriers. The unit cost of each element is defined without reference to the services provided by the network elements included in the TELRIC cost study.

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[29] *In the Matter of Federal-State Joint Board on Universal Service*, Report and Order, CC Docket No. 96-45 (released May 8, 1997) at ¶250.

[30] 47 C.F.R. §51.505 (b).

To be consistent with the Commission's forward-looking principles a wireless cost model would begin with a scorched-node baseline in which the location of the MSCs is taken as fixed, but *no* infrastructure is deployed and no services are produced. The increment would be the projected volume of basic voice service within an MTA, the area relevant for local interconnection.

A wireless cost model would ensure that the *total* quantity of each network component used to provide a transport and termination service is included when costs are computed. That is, the quantity of each component includes the amount used to terminate interconnected calls and also the amount used to originate and terminate all other calls. As with cost proxy models of wireline networks, a wireless cost model would flow through the benefits of economies of scale to interconnected calls in proportion to their share of all calls carried by the network. Using the total volume of calls results in estimated costs that tend to be lower than would be the case if only interconnected calls were used.

For incumbent LECs, the Commission has determined that a forward-looking cost methodology should model a local network that will efficiently satisfy "reasonably foreseeable capacity requirements."[31] In the context of mature wireline networks, current demand augmented by a fill factor may provide reasonable estimates of capacity requirements. For new and rapidly growing networks, "reasonably foreseeable capacity requirements" in the near term are likely to be far greater than current demand. Indeed, networks sized to meet only current demands will not be adequate to meet demands in the near future. The unit cost of such networks is likely to be high, since the designed network will not benefit from significant economies of scale that will be realized in the near future. A network that minimizes the discounted cost of serving a growing demand profile over a reasonable time horizon will have a lower cost than either a network designed to meet current demand alone, or a network that is expanded continuously to keep pace with growing demand.

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[31] "We, therefore, conclude that the forward-looking pricing methodology for interconnection and unbundled network elements should be based on costs that assume that wire centers will be placed at the incumbent LEC's current wire center locations, but that the reconstructed local network will employ the most efficient technology for reasonably foreseeable capacity requirements." Local Competition Order at ¶685.

A wireless cost model should meet the FCC's requirement that the modeled network satisfy reasonably foreseeable capacity requirements by using a forecast of anticipated growth, rather than basing capacity requirements entirely on current demand, as the wireline cost proxy models do. Given the high growth rate of demand, the rapid change in wireless technologies (such as the expected introduction of third-generation technology in three years), and the unpredictable growth of new wireless applications enabled by new technologies, neither the levels of demand nor the assets required to meet demand are likely to be "reasonably foreseeable" more than three years into the future. Using a three-year study period, demand should be forecast for each year, and the model should minimize the costs of meeting demand over the period by deploying assets in accordance with the best current engineering practice.

It should be noted that the new PCS entrants are independent companies or separate subsidiaries that are not subject to cost-based regulation that can distort their investment incentives. A new entrant has strong incentives to minimize cost in order to compete for subscribers in a market characterized by well-established cellular providers and other aggressive new entrants. Also, new entrants' networks do not contain legacy investments made decades earlier, but are comprised of assets that represent the current state of the art. For both of these reasons, a wireless cost model for a new entrant can reasonably assume that the base-year quantities of network assets are equal to those in its currently deployed network. The model should evaluate the replacement cost of the base network using current prices. This treatment of investments is consistent with a forward-looking approach to costs.

In contrast to a wireless network, in an ILEC network the calculation of forward-looking costs cannot reliably use the incumbent's currently deployed network as a baseline. The current ILEC network may be very different from an efficient, forward-looking network using the best currently available technology for two reasons. First, wireline ILECs' current networks have grown incrementally over several decades and have inherited a legacy of older assets, technologies, and systems that are not efficient when compared to currently available alternatives. Second, many ILECs continue to own and operate assets that were acquired when they were subject to some form of cost-plus regulation. Since this form of regulation is known to create incentives to over-invest, the embedded investment in ILEC networks would be inefficient even when compared to alternatives that were available at the time the investments were made. *A fortiori,* these investments would be inefficient when compared to the best currently available technology.

Like cost proxy models of incumbents' networks, a wireless cost model should convert investments to annual costs using annual charge factors (ACFs) derived from assumed forward-looking values for the cost of capital, economic lives for each asset, and applicable tax rates and loading factors to account for the expenses of operating and maintaining the assets. The assumed values of these input parameters can be based on the business experience of the wireless company. The model can then account for forward-looking common costs by applying a proportional mark-up factor to the long-run incremental cost of each service.

4.2 Computing Levelized Prices

In a network with rapidly growing demand, the unit cost of a service will decline as capacity utilization increases and economies of scale are achieved. A constant price can be charged to all units of demand in order to recover all of the costs incurred over a several-year study period. To calculate such a levelized price, p, let Q_i be the forecast demand (minutes of use, with a given time-of-day and spatial pattern over the service area) in the i^{th} year of an N year period.[32] Let C_i be the cost in year i of an efficiently designed network that can supply Q_i units of output in year i. C_i is the sum of the annualized cost of the investment program, the expenses incurred in year i to operate and maintain the network, and a pro-rated share of common costs as described in the previous section. At this price the present values of revenues and costs, discounted by the discount factor d, are:

[32] For expositional convenience, we consider the simple case in which output is a scalar. However, the approach described below can in principle be used to develop levelized prices for multiple services. In such cases, the prices of the different services could be different from one another, but any one service's price would be constant over time.

$$\text{Discounted revenue} = \Sigma d^{i-1} p\, Q_i$$

$$\text{Discounted cost} = \Sigma d^{i-1} C_i$$

Equating discounted revenue to discounted cost and solving for the levelized price yields

$$p = \Sigma d^{i-1} C_i / \Sigma d^{i-1} Q_i$$

This levelized price is thus equal to the discounted costs divided by the *discounted* minutes of use. It has two attractive features. First, it just recovers forward-looking economic costs. Second, it shares future cost savings from economies of scale equally across all minutes of use in the study period, including minutes of use early in the period when scale economies have not yet been realized. As a result, the unit cost of transport and termination on PCS networks computed by such a wireless model would be lower than the unit cost based on first-year annualized costs alone.

4.3 Forward-Looking Cost of Spectrum Licenses

Obtaining spectrum for use in their networks is a significant cost for PCS network operators. However, a precedent on the forward-looking treatment of these costs is not available from earlier Commission proceedings because wireline incumbents and traditional cellular providers have not incurred such costs.

Current market prices can provide a useful starting point for estimating the forward-looking cost of an asset. However, subsequent to the initial public auction of spectrum licenses for PCS, licenses have not been widely traded in an active marketplace, and the terms of the few recent transactions are not public. There appear to be large transactions costs in transferring spectrum rights. Consequently, the development of forward-looking spectrum costs from current market prices of licenses is likely to be difficult. In this section we consider the use of both secondary market and auction prices for spectrum licenses, the additional costs of clearing spectrum purchased at auction, and the economic life of a license.

4.3.1 Secondary Market Prices for Spectrum Licenses

Spectrum licenses for cellular service were awarded in 1982 by lotteries in which several licenses were won by speculators who later sold them to cellular service providers. There appears to be some agreement that the post-lottery market for cellular licenses was not efficient. According to one expert, "[T]he need to buy licenses from the auction winners ... may also have contributed to the geographic fragmentation of the cellular industry, delaying the introduction of mobile telephone services that would work wherever the consumer traveled in the United States."[33] Another observer commented: "It took a decade of negotiations and private auctions for the eventual service providers to acquire desirable packages of licenses from lottery winners."[34]

In contrast to cellular spectrum licenses, PCS spectrum licenses were initially sold at public auctions. There is little information available on post-auction transactions involving spectrum allocated for PCS: "In the first two years there has been little resale. GTE is the one exception. Shortly after the MTA auction ended, GTE sold its MTA winnings for about what it paid for the licenses."[35]

Given the apparently high transactions costs of purchasing a spectrum license initially awarded in the cellular license lottery, and the lack of a substantial volume of transactions following the PCS auctions, it would be problematic to evaluate the forward-looking economic cost of a spectrum license from secondary market transactions. However, there is considerable evidence that prices established in the PCS spectrum auctions, which gave bidders the opportunity to bid simultaneously for licenses across many geographic areas, were efficient.[36] We therefore

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[33] Paul Milgrom, *Auction Theory for Privatization*, Chapter 1, "Auctioning the Radio Spectrum," Cambridge University Press, forthcoming.

[34] Peter Cramton, "The Efficiency of FCC Spectrum Auctions," *Journal of Law and Economics*, 41 (October 1998): 727-736, p. 728.

[35] Cramton, p. 731.

[36] See Cramton, *op. cit.*, and Milgrom, *op. cit.*

consider an alternative approach based on final prices at the PCS spectrum auctions that is consistent with a forward-looking methodology.

4.3.2 Auction Prices for Spectrum Licenses

The licenses obtained at auction vary in several dimensions including bandwidth, geographic and population coverage, and the degree to which the spectrum is encumbered by incumbents. For example, in the broadband PCS auctions that were concluded in 1995, Sprint PCS won several licenses for either 10 MHz or 30 MHz of spectrum. Frequency bands awarded to Sprint PCS were occupied by incumbents who could be relocated to other bands (or to non-wireless facilities) only at Sprint PCS's expense. For PCS operators, spectrum was a lumpy and encumbered investment, in contrast to the unencumbered spectrum cellular carriers had earlier obtained at no charge.

The terms of the PCS auction have determined, to a considerable degree, the terms on which spectrum can currently be obtained and used.[37] The long-run variability of inputs assumed in forward-looking cost models is limited by the "lumpiness" of spectrum arising for technical or transactional reasons that can be traced back to the PCS auction. An efficiently configured network must account for this lumpiness. Since PCS licenses were for either 10 MHz or 30 MHz of (encumbered) spectrum, these are the natural units to consider in a forward-looking cost study of the transport and termination of interconnected calls on PCS networks.

In some densely populated markets where Sprint PCS has 10 MHz licenses, it currently uses its entire licensed spectrum and is seeking more spectrum to serve increases in demand. If additional spectrum becomes available, the least-cost design of the network may be based on the use of more than 10 MHz of spectrum. However, without a well-organized post-auction market for spectrum, spectrum license transactions are rare and idiosyncratic. A PCS operator cannot safely assume that its need for additional spectrum can be satisfied by purchases. Indeed, in

[37] As mentioned, Cramton, p. 731, notes that GTE's sale of a PCS license was at a price approximating its winning bid.

markets where Sprint PCS experiences high demand for PCS services, it is likely that other licensees will also face high demand, and no suitable spectrum will be available.[38] Increases in demand may have to be met through cell splitting, and the theoretical long-run, low-cost solution using more spectrum may be infeasible. In these markets, an engineering cost model based on 10 MHz of spectrum may be appropriate for computing the forward-looking costs of transport and termination. The cost of the spectrum can be based on the amount paid at auction.

In some sparsely populated markets, 30 MHz of spectrum may be more than sufficient to meet projected demand even in the long term. Even in these cases, the price paid for a 30 MHz license at auction represents an appropriate starting point for estimating the forward-looking cost of spectrum. In the PCS auctions for the A and B bands, 99 licenses, each for 30 MHz blocks of spectrum, were sold. The winning bids reflected the large differences in the populations and demographic characteristics of the licensed markets, which ranged from 26.4 million people in the New York MTA to 47,000 in American Samoa, as bidders recognized that less revenue would be earned in less populous MTAs and adjusted their bids accordingly.[39] A winning bid incorporates the expectation that some fraction of the licensed spectrum may not have any use-value or resale value to the winner. Thus, even when a forward-looking network *design* calls for less than 30 MHz of spectrum, the appropriate starting point for estimating the forward-looking *cost* is the final auction price for the entire 30 MHz band. The same logic would apply to 10 MHz licenses.

An auction bid might include a premium above the spectrum's use-value in a PCS network if the bidder expected to sell some unused spectrum in the future. However, such sales will occur only when another provider or consumer has use for spectrum that the licensee's customers and potential customers do not demand. As a practical matter, these opportunities to sell a portion of

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[38] PCS providers may be able to increase the amount of available spectrum by relocating incumbents who use encumbered spectrum. The costs of incumbent relocation are discussed below.

[39] Milgrom, *op. cit.*, p. 37.

licensed spectrum are uncommon, have high transactions costs, and can best be dealt with on a case-by-case basis.

4.3.3 Costs of Incumbent Relocation

At the time spectrum was allocated for PCS, the frequencies were partially occupied by incumbent licensees — mostly utilities, railroads, petroleum companies, and local governments — who operated some 4,500 point-to-point microwave links in these bands. All MTAs were not equally encumbered, although in "some areas with high concentrations of incumbents, the interference constraints could prevent a PCS licensee from offering a competitive service."[40] Legislation and Commission rules established a framework to govern negotiations between incumbents and entrants to relocate the incumbents.[41] By 1998, approximately half of the incumbent links had been moved to alternate bands or wireline facilities, or had been terminated pursuant to the negotiations.

Commission rules permitted incumbents to keep their links and required the PCS entrant to compensate an incumbent for the costs of relocation to a comparable alternative. A bargaining theory analysis of the effect of the Commission's incumbent relocation rules on the costs of relocation incurred by entrants suggests that incumbents can successfully obtain payments in excess of the actual costs of relocation. Its authors conclude: "While there are no public records of payments made for relocation, it appears that the microwave incumbents have been able to extract some premiums, but that the premiums have been limited. Good faith negotiations appear to have been the norm although there are numerous reports of large demands for rapid settlement."[42] In one case, an equipment manufacturer estimated that an incumbent's relocation cost would be $225,000 per link and the incumbent demanded $400,000 per link. Before the

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[40] Peter Cramton, Evan Kwerel and John Williams, "Efficient Relocation of Spectrum Incumbents," *Journal of Law and Economics* 41 (October 1998): 647-675, p. 661.

[41] Cramton et al., Section 5.

[42] Cramton et al., p. 668.

licensee could respond to this offer, the incumbent escalated the demand to $1.2 million per link.[43]

Because public disclosure of a high incumbent relocation payment by one PCS licensee would likely lead to demands for higher payments from other incumbents, PCS licensees are likely to insist on non-disclosure of any high relocation payments they may make. Consequently, estimates of relocation payments based on publicly available information can be biased downwards.

Estimates of relocation costs that are based solely on engineering studies are likely to underestimate the costs of clearing encumbered spectrum. Even when such estimates are augmented with publicly available information on relocation payments, the resulting estimates may still underestimate the full costs paid by at least some PCS licensees. A wireless cost model would properly include the actual payments made to incumbents as part of the cost of spectrum.

4.3.4 Economic Life of Spectrum Licenses

The Commission's rules for a forward-looking cost methodology require that the annual costs of any asset, including spectrum be calculated using the economic life of the asset, the firm's cost of capital and the relevant tax rates.[44] Spectrum does not physically depreciate and for practical purposes has an infinite (or indefinite) physical life. However, the license authorizing a carrier to use the spectrum has a limited duration, typically ten years. At the end of the license period, it is expected that the license will be renewed for a subsequent period. The economic life of the asset to the carrier will generally be greater than the initial license period of ten years but less than the infinite physical life. If the market expected that PCS licenses would be renewed once without any material changes in the license terms and conditions, the market value of the licensed spectrum would be based on the discounted residual cash flow that could be earned

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[43] Id.

[44] 47 C.F.R. Ch. 1 §51.505 (b)(2).

from the sale of services produced with the spectrum over 20 years, and the economic life would be 20 years.

In the absence of an active market or information on the expectations of potential purchasers of spectrum licenses, three approaches appear to have some merit. First, the life of the asset can be assumed to be equal to the life prescribed in the tax code. Second, the economic life of the asset can be based on generally accepted accounting principles, which call for amortizing intangible assets over a period not to exceed 40 years.[45] Third, a wireless cost model could treat spectrum in the same way that land is treated in wireline cost proxy models. The FCC's cost model assumes that both the land and buildings required to house wire centers have an economic life of 46.93 years.

5 Conclusion

Pursuant to the pricing standards contained in section 252(d)(2) of the Telecommunications Act of 1996, each carrier in a reciprocal compensation arrangement is entitled to recover its additional costs of terminating interconnected calls on its network. A large number of network components is used to terminate calls on a PCS Network--the handset, the wireless link to the cell sites, the cell sites including structures, antennas and BTSs, links from the cell sites to the BSCs, the mobile switches, an intelligent network platform and the associated SS7 signaling network. To apply the Commission's rate standard in a PCS network, we inquired whether each component of the network is shared by several users or whether it is dedicated to a single user. Next, we considered whether each component's costs are traffic sensitive. Our analysis found that the costs of each component of a PCS network, excepting handsets, are additional costs as defined by the Commission and should be included in any cost study to establish the appropriate rate for transport and termination on a PCS network.

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[45] *Generally Accepted Accounting Principles, AIN-APB17, Intangible Assets: Unofficial Accounting Interpretations of APB Opinion No. 17.*